These multiplexers make it possible, on the one hand, to make better use of the bandwidth of the optical channels and, on the other hand, to reduce the number of selective lasers necessary for wavelength multiplexing.

Contemporary multiplexers, in particular multiplexers used in SONET/SDH data transmission, are costly and very complex. Such multiplexers have the disadvantage that they only permit data streams or SDH data signals which are configured in accordance with the synchronous digital hierarchy SDH to be multiplexed, the multiplexers being configured in accordance with the ITU Recommendation G.707.

The present invention is directed toward achieving maximum or effective use of the transmission capacity made available by the communications network when a number of data streams having different data transmission rates are transmitted over a communications network; in particular, over an optical communications network.

SUMMARY OF THE INVENTION

In the method according to the present invention, data streams having different transmission rates are transferred between a first and second data transmission unit, the data streams to be transferred being inserted into data frames each having the same data volume and the same data transmission rate. An essential aspect of the method according to the present invention is that the data frames each have six subframes, a first and second stuffing check bit being arranged at the start of each of the second to sixth subframes. A first and second variable stuffing bit is arranged in the sixth subframe, following the first and second stuffing check bits. The data frames each have a data volume of 1360 bits.

An advantage of the method according to the invention is that it is possible to implement a transparent transmission of data streams having any desired data transmission rates, or a transparent transmission of information which is transferred using any desired data transmission method and has any desired data formats. Furthermore, optimum or maximum use of the transmission capacity made available by a communications network and/or optimum use of the bandwidth of a data transmission channel made available for transferring information is achieved.

By using a uniform data frame it is possible to dispense with complex pointer methods in multiplexers. Moreover, it is possible to reduce the number of selective lasers at the input of wavelength multiplexers which make available a data transmission channel.

Additional features and advantages of the present invention are described in, and will be apparent from, the following Detailed Description of the Invention and the Figures.

BRIEF DESCRIPTION OF THE FIGURES

FIG 1 shows a detail of a data transmission path.

FIG 2 shows a data frame for multiplexing a 2.666057 Gbps data stream.

FIG 3 shows a data frame for multiplexing a 2.488320 Gbps data stream.

FIG 4 shows a data frame for multiplexing 1.250 Gbps data streams.

FIG 5 shows a multiplex structure for forming the multiplex signal.

FIG 6 shows a data frame for a multiplex signal.

DETAILED DESCRIPTION OF THE INVENTION

FIG 1 shows a detail from a data transmission system in which wavelength multiplexers are arranged for, for example, N x 10 Gbps channels. In the data transmission system illustrated, a first data transmission unit representing a terminal multiplexer MUXE is arranged, via which data signals or data streams e1, e2, e31, e32 which are present at inputs EM1...4 and have different data transmission rates are combined.

For this exemplary embodiment it will be assumed that a data signal e1 having a data transmission rate of 2.666057 Gbps or a data stream e1 having a data transmission rate of 2.666057 Gbps is fed to the first input EM1 of the multiplexer MUXE. This data signal or data stream is specified by the ITU-T in the Recommendation G.975 and describes an STM-16/OC-48 signal with FEC (Forward Error Correction). A 2.488320 Gbps data signal e2 or a data stream e2 having a transmission rate of 2.488320 Gbps is fed to the second input EM2 of the multiplexer MUXE. This data signal e2 is specified by the ITU-T in the Recommendation G.707 and describes an STM-16/OC-48 signal. Furthermore, in each case a 1.250 Gbps data signal or in each case a data stream e31, e32 having a

data transmission rate of 1.250 Gbps is fed to the third and fourth inputs of the multiplexer MUXE. This data signal e31, e32 is specified BY IEEE P 802.3 and describes a data signal referred to as “Gigabit-Ethernet”.

The output signal which is present at the output AM of the terminal multiplexer MUXE is passed on to a wavelength multiplexer WDM. The data which is directed via a wavelength multiplexer WDM is transmitted, for example, via optical or electric amplifiers OA, ER and further wavelength multiplexers WDM, to a data transmission unit which is arranged at the end of the data transmission system and also represents a terminal multiplexer MUXA.

The data signals or data streams e1, e2, e31, e32 which are present at the four inputs EM1...4 are each inserted into data frames, also referred to as containers, DR1...3 using a frame forming unit (not illustrated) which is arranged in the multiplexer MUXE, the data frames DR1...3 each having the same data volume and the same data transmission rate. The data frames DR1...3 which are formed and the data signals e1, e2, e31, e32 which are inserted into the data frames DR1...3 are subsequently multiplexed by the multiplexer MUXE and converted into a multiplex signal a which represents the output signal.

FIG 2 illustrates a first data frame DR1 for multiplexing the 2.666057 Gbps data signal e1 (STM-16/OC-48 with FEC). The 2.666 Gbps data signals e1 which are specified in accordance with the Recommendation G.975 can be plesiochronous with respect to one another and when they are they can have a maximum deviation from the setpoint frequency of 4.6 ppm (parts per million). The first data frame DR1 has 6 subframes UR1...6. In the first subframe UR1, 225 data bits of the 2.666 Gbps data signal e1 are transmitted as user data nd. A first and second stuffing check bit C1, C2 are arranged at the start of each of the second to sixth subframes UR2...6. In the sixth subframe UR6, a first and second stuffing bit S1, S2 are additionally arranged following the two stuffing check bits C1, C2. 225 databits are transmitted in each of the second to fifth subframes UR2...5 following the two stuffing check bits C1, C2, and 223 data bits of the 2.66 Gbps data signal e1 are transmitted as user data nd in the sixth subframe UR6 following the two stuffing check bits C1, C2 and the two stuffing bits S1, S2.

The first data frame DR1 has in total a data volume of 1360 bits, of which, depending on the status or use of the two stuffing bits S1, S2, 1348 to 1350 bits can be used for transferring data bits of the 2.666 Gbps data signal e1 as user data nd. In order to permit the data signal e1 present at the first input EM1 of the multiplexer MUX to be multiplexed, a stuffing method is used. For example, a positive stuffing method can be used. In this stuffing method, the stuffing information is transmitted in the first and second stuffing check bits C1, C2, the first and second stuffing check bits C1, C2 each indicating whether or not the two stuffing bits S1, S2 are filled with user information. For example, if the bit combination "00000" is assigned to the first stuffing check bits C1, this indicates that the first stuffing bit S1 is used to transfer data bits of the data signal e1. If the bit combination "11111" is assigned to the first stuffing check bits C1, this indicates that the first stuffing bit S1 is a stuffing bit. In order to protect against individual bit errors in the stuffing check bits C1, C2 arranged in the first data frame DR1, a majority decision is advantageously carried out.

Depending on the use or status of the two stuffing bits S1, S2 arranged in the first data frame DR1, 1348 to 1350 data bits of the first data signal e1 are transmitted as user data nd by the first data frame DR1. When a positive stuffing method is used, the data transmission rate of the first data frame DR1 is selected such that in the nominal case,1349 user data bits nd are transmitted per data frame. This leads to a nominal bit rate of the first data frame DR1 of 2.666057 Gbps x 1360 bits / 1349 bits = 2.687796 Gbps.

The stuffing method used thus permits fluctuation of the data transmission rate of the data signal e1 inserted into the first data frame DR1 within the following limits f_o, f_u:

f_o = 2.687796 Gbps x 1350 bits/1360 Bits = 2.668032 Gbps

f_u = 2.687796 Gbps x 1348 bits/1360 bits = 2.664080 Gbps.

The derived limits f_o, f_u of the data transmission rate of the first data signal e1 correspond to an acceptable deviation of 2.668032/2.666057 = 1.000741, which corresponds to an acceptable deviation of 741 ppm. This is higher than the

maximum frequency deviation of a transmission signal of 4.6 ppm which is permitted in accordance with ITU Recommendation G.813, page 3, chapter 5.

FIG 3 illustrates a second data frame DR2 for multiplexing the 2.488320 Gbps data signal e2. For the second data frame DR2 which also has six subframes UR1...6, the same stuffing method as in the first data frame DR1 is used. In contrast to the first data frame DR1 illustrated in FIG 2, in the case of the second data frame DR2 fifteen times fourteen data bits 14D of the second data signal e2 as user data followed by a fixed stuffing bit R are alternately transmitted in the user data field nd of each of the first to fifth subframes UR1...5. In the sixth subframe UR6 of the second data frame DR2, 12 data bits 12D of the second data signal e2 are transmitted as user data followed by a fixed stuffing bit R, and subsequently fourteen times fourteen data bits 14D of the second data signal e2 as user data followed by a fixed stuffing bit R are alternately transmitted in each case.

The second data frame DR2 also has a data volume of 1360 bits, 1258 to 1260 data bits being transmitted by the second data frame DR2, depending on the use and/or status of the two stuffing bits S1, S2.

In order to permit subsequent multiplexing of the first and second data frames DR1, DR2 formed, the second data frame DR2 has the same data transmission rate as the first data frame DR1. The stuffing method which is used with the second data frame DR2 thus permits the data transmission rate of the data signal e2 inserted into the second data frame DR2 to fluctuate within the following limits f_o, f_u:

f_o = 2.687796 Gbps x 1260 bits/1360 bits = 2.490164 Gbps

f_u = 2687796 Gbps x 1258 bits/1360 bits =
2.486211 Gbps.

The derived limits f_o, f_u of the data transmission rate of the second data signal e2 correspond to an acceptable deviation of 2.490164/2.488320 = 1.000741, which corresponds to an acceptable deviation of 741 ppm.

FIG 4 illustrates the third data frame DR3 for the simultaneous multiplexing of two 1.250 Gbps data signals e31, e32, which are also referred to as Gigabit-

Ethernet data signals according to IEEE P802.3. The third data frame DR3 also has six subframes UR1...6, a first and second stuffing check bit C1, C2 being arranged at the start of each of the second to sixth subframes UR2...6. In addition, first and second stuffing bits S1, S2 are arranged in the sixth subframe UR6, following the two stuffing check bits C1, C2. The data bits of the two 1.250 Gbps data signals e31, e32 to be transferred are inserted into the subframes UR1...6 after alternate or bit interleaving; i.e., the six subframes UR1...6 in each case alternately transfer one bit of the first Gigabit-Ethernet signal e31 and one bit of the second Gigabit-Ethernet signal e32. The first stuffing check bits C1 and the first stuffing bit S1 are assigned here to the first Gigabit-Ethernet signal e31, and the second stuffing check bits C2 and the second stuffing bit S2 are assigned to the second Gigabit-Ethernet signal e32. In contrast with the second data frame DR2 illustrated in FIG 3, in the case of the third data frame DR3, fourteen data bit groups (14D) with a data volume of fourteen bits each are inserted in the user data field nd of each of the first to fifth subframes UR1...5, each of the data bit groups (14D) being followed by a fixed stuffing bit (R). In addition, a data bit group (15D) having a data volume of 15 bits is inserted in each of the first to fifth subframes. A data bit group (12D) having a data volume of twelve bits, followed by a fixed stuffing bit (12), and thirteen data bit groups (14D) each having a data volume of fourteen bits and each followed by a fixed stuffing bit (R), and a data bit group (15D) having a data volume of fifteen bits are inserted into the sixth subframe UR6. The data bits of the two Gigabit-Ethernet signals e31, e32 are transmitted after bit interleaving as user data in each of the data bit groups (12D, 14D, 15D) which were inserted into the six subframes UR1...6.

The third data frame DR3 illustrated in FIG 4 has a data volume of 1360 bits, of which in each case 632 or 633 data bits are transmitted as user data, depending on the use and/or status of the stuffing bits S1, S2 for each of the two Gigabit-Ethernet signals e31, e32. In order to permit the third data frame DR3 to be multiplexed with the first and second data frames DR1, DR2, the third data frame DR3 has the same data transmission rate as that of the two data frames DR1, DR2 already described. The stuffing method used in the case of the third data frame DR3

thus permits the data transmission rate of the Gigabit-Ethernet signals e31, e32 which are respectively inserted into the third data frame DR3 to fluctuate within the following limits f_o, f_u:

f_o = 2.687796 Gbps x 633 bits/1360 bits = 1.252011 Gbps

f_u = 2.687796 Gbps x 632 bits/1360 bits = 1.249035 Gbps

The derived limits f_o, f_u of the data transmission rates of the two Gigabit-Ethernet signals e31, e32 correspond to an acceptable deviation of 1.250/1.249035 = 1.000772, which corresponds to an acceptable deviation of 772 ppm.

FIG 5 illustrates in a self-explanatory fashion a multiplex structure for forming a multiplex signal. By way of example, it will be assumed that in each case four frame signals each representing one of the data frames DR1...3 are multiplexed in any desired combination to form a multiplex signal as. According to FIG 5, the four input signals e1, e2, e31, e32 are inserted into the corresponding data frames DR1...3 as a function of their data transmission rate, the data transmission rates of the inserted data signals e1, e2, e31, e32 being adapted to the uniform data transmission rate of the data frames DR1...3 by inserting fixed stuffing bits and via the stuffing method described. The data frames DR1...3 formed are then bit interleaved using multiplexer AUG. In a following frame forming unit STM, for example a "synchronous transport module" STM, a frame alignment word RKW and corresponding overhead information OU are added to the interleaved data signal or data stream and the multiplex signal as is formed therefrom.

The multiplex signal as which is formed is subsequently transferred via the communications network to the destination multiplexer MUXA which is illustrated in FIG 1 and in which the received multiplex signal as is demultiplexed again into the data frames DR1...3 or into the data signals e1, e2, e31, e32 inserted therein.

FIG. 6 illustrates an exemplary refinement of the multiplex signal as formed. At the start of the multiplex signal as, the frame alignment word RKW, which has a data volume of 16 bits, is arranged. The overhead information OH having a data volume of 8 bits is arranged following the frame alignment word RKW.

The multiplex signal as illustrated is also subdivided into six subframes UR1...6, the six subframes having in total a data volume of 5464 bits. The data bits of any desired combination of four data frames DR1...3 which are formed are inserted after bit interleaving into the six subframes UR1...6. Via the bit interleaving of any respective desired combination of four data frames DR1...3 which are formed, the respective subframes UR1...6 of the four data frames C1...4 are correspondingly combined or multiplexed; for example, the respective first subframes UR1 of the four data frames DR1...3 which are combined in the multiplex signal as are arranged in bit-interleaved form in the first subframe UR1 of the multiplex signal as. The first and second stuffing check bits C1, 2 which are arranged in each of the second to sixth subframes UR2...6 of the multiplexed data frames DR1...3 are arranged at the start of each of the second to sixth subframes UR1...6 of the multiplex signal as, and the first and second stuffing bits S1,2 of the multiplexed data frames DR1...3 are correspondingly subsequently arranged in the sixth subframe UR6 of the multiplex signal.

The data transmission rate of the multiplex signal as is obtained as:

$f_m = 2.687796$ Gbps x 5464/1360 = 10.798616 Gbps

It is to be noted that any desired data frames DR1...3 with any desired data volume and data transmission rates can be formed using the method according to the present invention, the data frames DR1...3 being multiplexed to form any desired multiplex signals as. As a result, optimum input signals which are adapted to the transmission channels of the wavelength multiplexers can be provided for the wavelength multiplexers. For example, according to one embodiment (not illustrated) eight of the input signal e1, e2, e31, e32 described are fed to the multiplexer MUXE, the input signals e1, e2, e31, e32 which are fed in being multiplexed to form a 20 Gbps multiplex signal as.

Although the present invention has been described with reference to specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the spirit and scope of the invention as set forth in the hereafter appended claims.